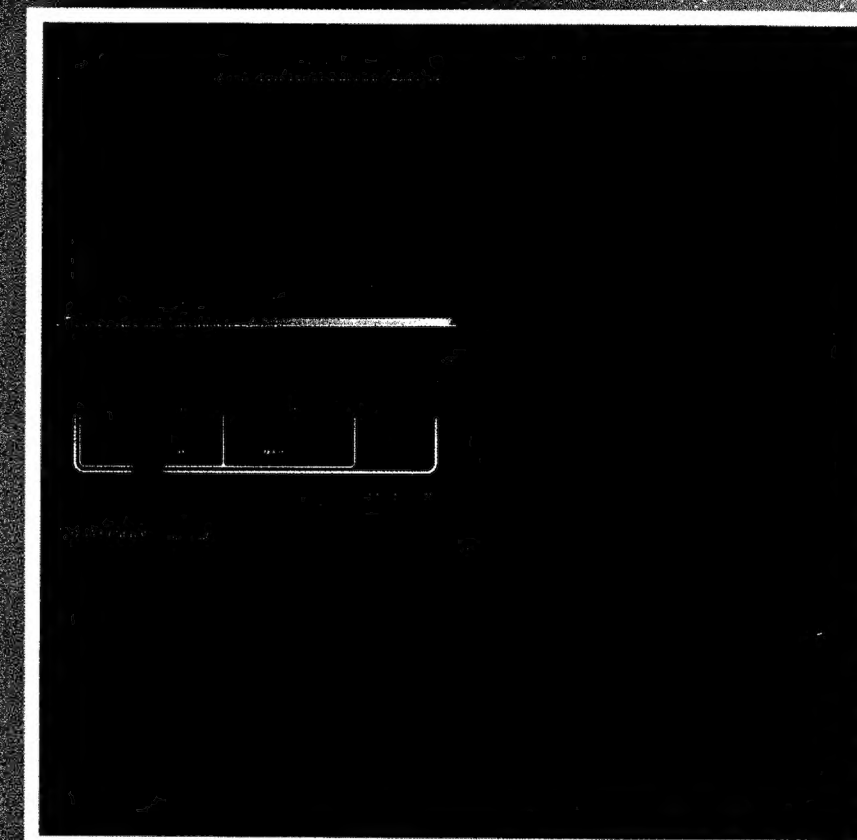


Programmer's Reference Series

Model 6097/6098/6099/6100/6103 DG/Disc Subsystems



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Programmer's Reference Series

**Model 6097/6098/6099/6100/6103
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PREFACE

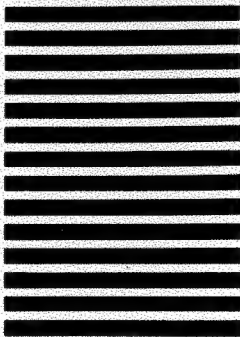
This manual describes the 6097, 6098/6099 and 6100/6103 DG/Disc subsystem architecture from a programming viewpoint. It presents the instruction set and discusses programming methods.

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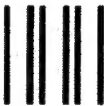
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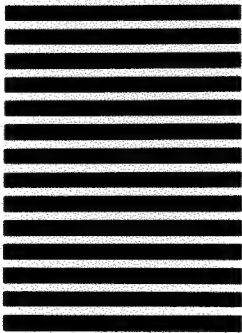
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Model 6097/6098/6099/6100/6103
DG/Disc Subsytems

PROGRAMMING SUMMARY

SUBSYSTEM SPECIFICATIONS

Mnemonic (First Controller)	DKP
Device Code (First Controller)	33 ₈
Mnemonic (Second Controller)	DKP1
Device Code (Second Controller)	73 ₈
Mask bit	7
Units per subsystem	See table on page 3.
Maximum Capacity and capacity per unit	See table on page 3.
Data encoding method	Modified frequency modulation

DRIVE SPECIFICATIONS

	Rigid Drive	Flexible Drive
Surfaces/unit	6098/6099:2 6100/6103:4	2
Heads/surface	2	1
Tracks/head	192 (0-277 ₈)	77 (0-114 ₈)
Sectors/track	32 (0-37 ₈)	16 (0-17 ₈)
Bytes/sector	512 (1000 ₈)	512 (1000 ₈)
Data transfer rate		
Between disc and buffer	910,541 bytes/sec	n/a
Between buffer and data channel	Processor dependent	62,500 bytes/sec
Data channel latency	n/a (sector buffer)	50 μsec max.
Track access time	1 track-15msec 1/3 stroke-60 msec full stroke-130 msec	3 msec/track + 22 msec settle delay
Recalibrate time	540 msec max.	251 msec max.
Head load time	n/a	52 msec
Rotational speed	49.4 rev/sec	6 rev/sec
Rotational latency	10.1 msec ave.	83.3 msec ave.

ACCUMULATOR FORMATS*

SPECIFY COMMAND AND CYLINDER

CLEAR				COMMAND				CYLINDER			
0	1	2	3	4	5	6	7	8	9	10	11

Commands	
00	READ
01	WRITE
10	SEEK
11	RECALIBRATE

LOAD MEMORY ADDRESS REGISTER

MAP SEL	MEMORY ADDRESS													
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

SPECIFY DISC ADDRESS AND SECTOR COUNT

DR	FM MD	DG MD	STARTING HEAD	STARTING SECTOR				-SECTOR COUNT			
0	1	2	3	4	5	6	7	8	9	10	11

DOA

READ STATUS

R/W DN	SEEK DONE				FL	WR PR	BAD SEC	UN SF	RDY	SK ER	EOC	AD ER	CK ER	DT LT	ER
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

READ MEMORY ADDRESS

MAP SEL	MEMORY ADDRESS													
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

READ DISC ADDRESS AND SECTOR COUNT

DR	FM MD	DG MD	CURRENT HEAD	CURRENT SECTOR				-SECTOR COUNT			
0	1	2	3	4	5	6	7	8	9	10	11

*Valid when Diagnostic Mode flag is set to 0.

S, C AND P FUNCTIONS

f - S	Sets the Busy flag to 1, sets the Done flag to 0 and starts a read or write operation.
f - C	Sets the Busy and Done flags to 0 and terminates any operation in progress.
f - P	Sets the Done flag to 0 and starts a seek or recalibrate operation.
IORST	Performs the same functions as C. Also sets the Interrupt Disable flag to 0 and sets the Initial Program Load flag to 0.

Read Stepper Phase - Places the current phase of the stepping motor on the rigid drive in bits 12-15 of the Disc Address and Sector Count register.

Write Floppy Chip Track/Sector/Data Register - Transfers the contents of the low-order byte of the Disc Address and Sector Count register to the floppy controller chip's track, sector or data register.

Read Floppy Chip Track/Sector/Data Register - Transfers the contents of the floppy controller chip's status, track, sector or data register to the low-order byte of the Disc Address and Sector Count register.

Read DOA Bits 8-15 - Transfers the contents of the low-order byte of the Command and Cylinder Select register to the low-order byte of the Disc Address and Sector Count register.

Read Rigid Data Shift Register - Transfers the contents of the rigid drive's shift register to the Disc Address and Sector Count register. This field contains the address word following an address error or a read header operation, the CRC word following a read operation, and the backwards CRC word following a write operation.

No Operation - Transfer bits 0-15 of the Disc Address and Sector Count (DOC) register bits 0-15 of the Disc Address and Sector Count (DIC) register.

Read Disc Capacity - Reports the capacity of the rigid drive in bits 14 and 15 of the DIC register as follows:

Bit 14	Bit 15	Capacity
0	0	Reserved for future use.
0	1	Reserved for future use.
1	0	12.5 megabytes
1	1	25 megabytes

Extended Operations

These tests allow you to perform subsystem operations that cannot be selected by the normal command bits. (Note that, except for a read header operation on the rigid drive, all the extended operations return bits 0-7 of the Disc Address and Sector Count (DOC) register in bits 0-7 of the Disc Address and Sector Count (DIC) register.

Step In/Step Out One Track - Moves the positioner on the selected drive in to the next higher track number or out to the next lower number and then allows the heads to settle. If the rigid drive is selected, bits 7, 8 and 10-15 of the Status register are altered as described in the sequencer tests.

Start Data Channel - Starts a 256-word data channel transfer between the controller and the CPU. The direction is determined by bit 6 of the Command and Cylinder Select register. If the bit is set to 1, data flows from the CPU to the controller. If it is set to 0, data flows in the opposite direction. If the rigid drive is selected, data is transferred to or from the 256-word data buffer. If a flexible drive is selected, data is transferred to or from the data register in the floppy controller chip. (The controller must be placed in diagnostic mode if a flexible drive is selected.)

Test Sector Count Valid - Prompts the microprocessor to test the sector count valid signal from the rigid drive for proper timing. If the test fails, the Error flag (bit 0) in the Status register is set to 1.

Test Sector Counter - Prompts the microprocessor to test the Sector Count register in the rigid drive for proper sequencing. If the test fails, the Error flag (bit 0) in the Status register is set to 1, and the result of an exclusive-OR operation between the expected count and the actual count is placed in bits 11-15 of the Disc Address and Sector Count register.

Read Header Operation - Reads the address (header) field from the selected disc. If the rigid drive is selected, the address word is read from the surface and sector selected by the Disc Address and Sector Count register, and is then placed in that same register. It takes the following form:

TRACK				HEAD				SECTOR			
0	1	2	3	4	5	6	7	8	9	10	11

In addition, bits 7, 8 and 10-15 of the Status register are altered as described in the sequencer tests.

If a flexible drive is selected, the first header encountered is transferred to the CPU via the data channel, starting with the location specified by the memory address register. The three header words take the following form:

0	TRACK				0	0	0	0	0	0	0	0	HD
0	1	2	3	4	5	6	7	8	9	10	11	12	13

0	0	0	0	SECTOR				0	0	0	0	0	0	1	0
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

CRC														
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

In addition, the contents of the floppy chip's Status register are returned in bits 7, 8 and 10-15 of the Status register.

Bits 11-15	Diagnostic Command
00000	Set diagnostic mode
00001	*Simulate read/write clock
00010	*Start PROM operation
00011	*Simulate sector pulse
00100	Write DIA
00101	Step in one track
00110	Step out one track
00111	Start data channel operation
01000	*Test sector count valid
01001	*Test sector counter
01010	*Read disc capacity
01011	Read revision number
01100	Read track address
01101	*Read stepper phase
01110	No operation
01111	No operation
10000	Read header operation
10101	**Write floppy chip track register
10110	**Write floppy chip sector register
10111	**Write floppy chip data register
11001	**Read floppy chip track register
11010	**Read floppy chip sector register
11011	**Read floppy chip data register
11100	Read DOA bits 8-15
11101	*Read rigid data shift register
11110	Reset diagnostic mode

*Rigid operation only
**Flexible operation only

- These commands break down into three basic groups:
1. Sequencer tests
 2. Read/write register tests
 3. Extended operations.

Sequencer Tests

These commands are used primarily to test the hardware sequencers that direct the data transfer activities of the disc drives. The commands and their functions are as follows:

Set Diagnostic Mode - Places the controller in diagnostic mode.

Reset Diagnostic Mode - Places the controller in normal mode.

Simulate Read/Write Clock - Allows the program to step the serial read/write data clock to simulate a data transfer on the rigid drive. (Bit 10 of the Command and Cylinder Select register is used to simulate serial data during a read operation).

Start PROM Operation - Starts the hardware sequencer for the rigid drive.

Simulate Sector Pulse - Triggers the hardware sequencer for the rigid drive to begin a simulated data transfer. Before a sequencer test is started, the appropriate disc drive must first be selected by a *Specify Disc Address and Sector Count* instruction (**DOC**). Rigid sequencer tests are selected by bits 8, 9, 5 and 6 of the Command and Cylinder Address register as follows:

Bits				Operation
8	9	5	6	
0	0	0	0	Read
0	1	0	1	Write
1	0	0	0	Read header
1	1	0	1	Format

Whenever a sequencer test is specified, bits 7, 8 and 10-15 of the Status register are altered as follows:

Bits	Contents
7	Serial write data
8	Write gate
10	Read gate
11	PROM operation
12	Sector fault
13	CRC Error
14	Header error
15	Home

Read/Write Register Tests

These tests allow you to perform subsystem operations that cannot be selected by the normal command bits. (Note that except for a read header operation on the rigid drive, all the extended operations return bits 0-7 of the Disc Address and Sector Count (DOC) register in bits 0-7 of the Disc Address and Sector Count (DIC) register.

Write DIA - Transfers the information stored in bits 8-15 of the Disc Address and Sector Count register to bits 7, 8 and 10-15 of the Status register.

Read Revision Number - Places the revision number of the microprocessor's control program in bits 8-15 of the Disc Address and Sector Count register.

Read Track Address - Places the cylinder address of the currently selected drive in bits 8-15 of the Disc Address and Sector Count register.

INTRODUCTION

The 6097 DG/Disc Subsystem provides up to 5.04 megabytes of disc storage for NOVA and ECLIPSE line computers. It consists of a controller and up to four flexible disc drives.

The 6098/6099 DG/Disc Subsystems provide up to 13.7 megabytes of disc storage for NOVA and ECLIPSE line computers. Model 6098 is an integrated subsystem consisting of a controller and two moving head disc drives — a rigid disc drive with a storage capacity of 12.5 megabytes, and a flexible disc drive with a storage capacity of 1.2 megabytes. Model 6099 consists of the controller and the 12.5 megabyte rigid disc drive only.

The 6100/6103 DG/Disc Subsystems provide up to 26.2 megabytes of disc storage for NOVA and ECLIPSE line computers. Model 6100 is also an integrated subsystem consisting of a controller and two moving head disc drives — a rigid disc drive with a storage capacity of 25 megabytes, and a flexible disc drive with a storage capacity of 1.2 megabytes. Model 6103 consists of the controller and the 25 megabyte rigid disc drive only.

The following configurations are available:

Model	Capacity in MBytes (Rigid/Flexible)	Original Configuration	Maximum Expansion
6097-A	— /1.26	Controller 1 Flexible disc	1 Rigid disc and 2 Flexible discs or 3 Flexible discs
6097-B	— /2.52	Controller 2 Flexible discs	1 Rigid disc and 1 Flexible disc or 2 Flexible discs
6098	12.5/1.26	Controller 1 Rigid disc 1 Flexible disc	2 Flexible discs
6099	12.5/—	Controller 1 Rigid disc	3 Flexible discs
6100	25/1.26	Controller 1 Rigid disc 1 Flexible disc	2 Flexible discs
6103	25/—	Controller 1 Rigid disc	3 Flexible discs

Rigid Drive

The rigid drive used in the 6098/6099 subsystems contains a single non-removable recording disc. The rigid drive used in the 6100/6103 subsystems contains two non-removable recording discs. A recording disc has 384 tracks on each of its two data surfaces. There are two heads per surface to improve access times. Each head spans 192 (0-277₈) tracks. Each of the 32 (0-37₈) sectors in a track can store 512 (1000₈) data bytes. Data is recorded in modified frequency modulation (MFM) mode to achieve maximum

storage density. The drive employs Winchester technology heads and media to assure maximum reliability, high storage density and fast data transfers. Sectors are formatted with a special address field to allow the subsystem to detect access errors.

The rigid drive is self-contained in a 19 inch rack mountable chassis and includes its own power supply. A ribbon cable connects it to the subsystem controller.

Flexible Drive

The flexible drive accepts one removable double-density, double sided diskette. It is formatted with 77 (0-114₈) tracks on each of its two data surfaces. Each of the 16 (0-17₈) sectors in a track can store 512 (1000₈) data bytes. Data is recorded in MFM mode to achieve maximum storage density. The sector format includes a special address field that allows the subsystem to locate sectors. This "soft sector" format is necessary because the diskette does not have "hard" sectors marks to delimit sectors. (The soft sector arrangement requires you to format an entire track at once. This precludes reformat operations for selected sectors.)

The flexible drive in the model 6098 and the 6100 subsystems mounts on, and is powered by the rigid drive. A ribbon cable connects the flexible drive to the controller.

Controller

The controller is a standard 15 inch square board that resides in any I/O slot of a NOVA or ECLIPSE computer. A jumper allows you to configure it to support any of the subsystem models. The controller contains a microprocessor and a floppy disc controller chip. The microprocessor interprets commands, handles seek operations on the rigid drive and directs subsystem activities. The floppy disc controller chip handles seek and data transfer operations on the flexible drive(s).

Data is transferred via the data channel. Word transfers between the CPU and the flexible drive are double buffered to improve immunity to data channel latency. Transfers to and from the rigid drive are fully sector buffered. This is necessary to prevent the drive from exceeding the throughput capacity of the data channel. This means the the rigid drive cannot transfer contiguous physical sectors. The controller therefore supports a mapping function wherein every third physical sector is assigned a contiguous logical sector number.

The controller supports multiple sector transfers, and allows a data transfer operation beginning with one head to continue on the next head. It also performs extensive error checks, including cyclic redundancy checks (CRC) on recorded data. In addition, a bad sector flag can be set to prevent data transfers on defective sectors on the rigid drive. Finally, an initial program load feature can transfer a low-level bootstrap program from sector 0 on drive number 0 to the processor's memory bank.

CONTROLLER REGISTERS

The controller contains a Busy flag, a Done flag, four Seek Done flags and the following program accessible registers:

Register	Number Of Bits
Command and Cylinder Select	10
Memory Address	16
Disc Address and Sector Count	16
Status	16

The Command and Cylinder Select Register - stores an encoded subsystem command along with the cylinder address for a seek command.

The Memory Address Register - is self-incrementing and contains the address of the next memory location for a data channel transfer.

The Disc Address and Sector Count Register - specifies a drive number for a subsystem operation and specifies a starting head and sector number along with a sector count for a data transfer operation. It also contains a diagnostic mode flag and a format mode flag. (Note that the sector number and sector count are incremented after each sector is transferred. If a multiple sector transfer exceeds the capacity of the track, the sector number is reset and the head number is incremented.)

The Status Register - indicates subsystem status and flag errors.

The Busy flag - is set to 1 when a read or write operation is in progress.

The Done flag - is the same as the Read/Write Done flag and is set to 1 when a read or write operation is completed. The controller initiates a program interrupt request whenever the Done flag is set to 1. (Note that the Done flag is valid only after a read or write command has been issued.)

The Seek Done flags - indicate that a seek or recalibrate operation has been completed on the selected drive. The controller initiates a program interrupt request whenever a Seek Done flag is set to 1. (Note that a Seek Done flag is valid only after the drive has been selected and a seek or recalibrate command has been issued.)

The Ready flag can be set to 0 at any time in the succeeding phases and should therefore be checked at every programming stage.

If the Ready flag is set to 0 during a read, write or format operation, the operation is aborted. If the Ready flag is set to 0 during a seek or recalibrate operation, the operation is performed but the heads are not loaded. In either case, the Unsafe flag is also set to 1.

Errors While Positioning the Heads

Power Off - If the rigid drive is powered down while a seek or recalibrate operation is in progress on the flexible drive, the operation terminates and the Seek Error flag is set to 1.

Illegal Cylinder Address - If the program issues a *Specify Command and Cylinder* instruction (**DOA**) and initiates a seek operation to a non-existent cylinder (i.e., a cylinder number greater than 114₈), the operation terminates immediately and the Seek Error flag is set to 1.

Operation Timeout - If the selected drive fails to complete a seek or recalibrate operation within 1 second, the operation is terminated, the Seek Error flag is set to 1, and position information is lost. You will have to recalibrate the drive to recover position information.

Errors While Reading or Writing

Power Off - If the rigid drive is powered down during a read or write operation on the flexible drive, the operation is aborted and the Data Late flag is set to 1.

Write Protect - If a write or format operation is initiated on a write protected flexible drive, the Unsafe flag is set to 1 and the operation is aborted.

Illegal Head Address - If the program specifies a non-existent head number (i.e., a head number greater than 1) no error indication is given and head 0 or 1 is selected, depending on whether the specified head number is even or odd.

End of Cylinder Error - If the program specifies a multiple sector transfer that exceeds the capacity of the flexible drive (i.e., that attempts to proceed beyond the last sector on the second head), the operation terminates and the End of Cylinder flag is set to 1.

Address Error - The address Error flag is set to 1 and the operation is aborted if:

- The controller cannot find an address field that contains the required sector address.
- The controller cannot find an address field that contains the required track address (this may be due to a seek fault).
- The controller cannot find the data field during a read operation.
- The checkword appended to the address field didn't match the one the controller calculated when it read the field.

CRC Error - If the checkword appended to the data field didn't match the one the controller calculated when it read the field during a read operation, the Checkword Error flag is set to 1 and the operation is terminated immediately.

Data Late Error - If the processor's data channel fails to respond in time to a data channel request (i.e., the controller's data buffer overflowed during a read operation or underflowed during a write operation), the Data Late error flag is set to 1 and the operation terminates at the end of the current sector.

Operation Timeout - If the subsystem fails to complete a sector data transfer within 1 second from the time the command was initiated or the previous sector was transferred (for a multiple sector transfer), the operation is terminated, the Checkword Error and Data Late flags are set to 1 and position information is lost. This means you will have to recalibrate the drive.

DIAGNOSTIC COMMANDS AND FLAGS

This section explains the special operations that can be carried out under program control. This may help you to understand the diagnostic programs if you are troubleshooting the subsystem. We will not attempt to explain how the commands are used or how the hardware works.

Diagnostic commands are enabled when the Diagnostic Mode flag (bit 3 of the Disc Address and Sector count register) is set to 1. This overrides all other commands and may redefine the accumulator formats of the programming instructions.

The diagnostic commands are encoded in bits 11-15 of the *Specify Command and Cylinder* instruction (**DOA**). (These bits are normally used to specify a cylinder address for a seek operation.) The commands are as follows:

Illegal Cylinder Address - If the program issues a *Specify Command and Cylinder* instruction (**DOA**) and initiates a seek operation to a non-existent cylinder (i.e., a cylinder number greater than 277₈), the operation terminates immediately and the Seek Error flag is set to 1.

Operation Timeout - If the home zone is not found within a reasonable time during a recalibrate operation, the operation terminates and the Seek Error flag is set to 1.

Errors While Reading or Writing

Power Off - If the power switch is turned off, the operation terminates, a program interrupt request is initiated, the heads are moved to the landing zone, and the Error Flag is set to 1.

Write Protect - If a write or format operation is initiated when the Write Protect switch is set to 1, the Unsafe flag is set to 1 and the operation is aborted.

Speed Fault - If the disc's rotational speed falls below a preset minimum, the Unsafe flag is set to 1 and the operation terminates immediately.

Read/Write Fault - The operation terminates immediately and the Unsafe flag is set to 1 if:

- Write current is flowing during a read operation.
- Write current is not flowing during a write operation.
- More than one head is selected during a write operation.
- The serial data clock fails.

This error usually indicates a drive fault. In addition, data may be permanently destroyed.

Illegal Head Address - If the program specifies a non-existent head number (i.e., a head number greater than 3), the operation is attempted and the Unsafe and End of Cylinder flags are set to 1.

End of Cylinder Error - If the program specifies a multiple sector transfer that exceeds the capacity of the disc (i.e., that attempts to proceed beyond the last sector on the fourth head), the operation terminates and the End of Cylinder flag is set to 1.

Address Error and Bad Sector Flag - An address field precedes the data block in each sector. It indicates the track, head and sector number for that sector and also includes a bad sector bit. The controller performs an address check before it transfers the data block. If the address does not match the one expected by the controller, the Address Error flag is set to 1 and the operation terminates. If the bad sector bit is set to 1, the Bad Sector flag is set to 1 and the operation terminates.

If an address error occurs, the *Read Rigid Data Shift Register* diagnostic operation will allow you to examine the address word (see the diagnostics section). If the track address is incorrect, recalibrate the positioner and issue a new seek to the desired track (see the programming

section). If the head or sector address are incorrect, or the track address is still incorrect, retry the read or write operation. If errors persist after several retries, you may wish to reformat the sector (see the formatting section). You should be aware that this will destroy the data previously recorded in the sector.

If the Bad Sector flag is set to 1, the sector may be unusable due to a media defect. If the error persists after several retries, and you cannot successfully reformat the sector, you will not be able to write or read information in that sector.

CRC Error - Each time the subsystem writes data in the sector, it appends a 16-bit checkword to the 256 word data block. The checkword calculation is based on the data stream passing through the controller. During a subsequent read operation the controller again examines the data stream and calculates a new checkword. When all 256 words are read in, the controller compares the checkword it just calculated to the one that follows the data block (calculated during the previous write operation).

If they don't match, the Checkword Error flag is set to 1 and the read operation ends in the normal way. This indicates that a data error occurred somewhere in the data transcription process. The program may perform a *Read Rigid Data Shift Register* diagnostic operation to retrieve the checkword calculated during the read operation. This will be of limited use, however, as it is difficult to correct a faulty data block using the calculated checkword.

Operation Timeout - If the sector ends before the data block is transferred, the Unsafe flag is set to 1 and the operation terminates. (An operation timeout will occur if you attempt to read a sector that has no data recorded in it.)

Flexible Drive

When an error condition occurs and a visual inspection of the selected flexible drive shows nothing unusual, try to duplicate the fault with the original drive. If the fault persists, attempt to duplicate it on another flexible drive. Keep in mind that "soft errors" caused by airborne particles, random electrical noise, and other external causes may produce errors which are not the fault of the drive.

Errors During Initial Selection

If the Ready flag is set to 0 when a flexible drive is accessed, check the drive to see that:

- It is powered up.
- A double-sided/double-density disc (use Data General's Diskette/4 only) is installed.
- The door is closed.
- The disc is rotating.
- The unit select jumpers are properly installed.

INSTRUCTIONS

Six instructions program data channel data transfers to and from the subsystem. Three of these instructions supply the controller with all the information it needs to select a cylinder and initiate a data channel data transfer. The remaining three instructions allow the program to retrieve detailed status information.

The device flag commands and *I/O Reset* instruction **IORST** condition the controller as follows:

- f=S** Sets the Done, Read/Write Done and Seek Done flags to 0 and clears the error flags in the status register. Sets the Busy flag to 1 and starts a read or write operation.
- f=C** Sets the Busy, Done, Read/Write Done and Seek Done flags to 0 and clears the error flags in the status register. Terminates any operation in progress.
- f=P** Sets the Done, Read/Write Done and Seek Done flags to 0 and clears the error flags in the status register. Starts a seek or recalibrate operation. (Does not affect the Busy flags.)

IORST Performs all the operations listed under **f = C**. Also sets the Interrupt Disable flag to 0, clears the memory address register and sets the Initial Program Load flag to 1. Track position information is lost for all the drives in the subsystem.

NOTE: The following programming instruction descriptions assume that the *Diagnostic Mode* flag is set to 0. See the *Diagnostic commands* section for descriptions of the diagnostic instructions.

Specify Command and Cylinder

DOA[f] ac,DKP

0	1	1	AC	0	1	0	F	0	1	1	0	1	1		
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Loads bits 5 and 6 of the specified AC into the command register and loads bits 8-15 of the specified AC into the cylinder address register. Also clears all the Done flags if the clear function is specified by bits 0,1,2,3 or 4 of the specified AC, and sets the IPL flag to 0. After the data transfer, sets the controller's Busy and Done flags according to the function specified by F. The contents of the specified AC remain unchanged. The format of the accumulator is as follows:

CLEAR				COMMAND		0		CYLINDER									
0		4		5		6		7		8						15	

Bits	Name	Contents or Function
0-4	Clear	A 1 in any of these bits sets the Done, Read/Write Done and Seek Done flags to 0. Also clears the error flags in the status register.
5,6	Command	Specifies the command for the selected drive as follows: 00 Read 01 Write 10 Seek 11 Recalibrate
7	n/a	Reserved for future use.
8-15	Cylinder	Specifies the destination cylinder for a seek operation (0-277 ₈ for a rigid drive, 0-114 ₈ for a flexible drive). Also specifies the cylinder address for address checking during a read or write operation.

Load Memory Address Register

DOB[f] ac,DKP

0	1	1	AC	1	0	0	F	0	1	1	0	1	1		
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Loads bits 1-15 of the specified AC into the controller's memory address register. Also sets the controller's Map Select flag according to bit 0 of the specified AC. After the data transfer, sets the controller's Busy and Done flags according to the function specified by F. The contents of the specified AC remain unchanged. The format of the accumulator is as follows:

MAP SEL	MEMORY ADDRESS														
0	1														15

Bits	Name	Contents or Function
0	Map Sel	If set to 0, selects data channel map A. If set to 1, selects data channel map B.
1-15	Memory Address	Specifies the location of the first memory word for a data channel transfer.

Specify Disc Address And Sector Count

DOC[f] ac,DKP

0	1	1	AC	1	1	0	F	0	1	1	0	1	1		
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Loads bits 1 and 4-15 of the specified AC into the controller's Disc Address and Sector Count register. Also sets the controller's Format Mode and Diagnostic Mode flags according to bits 2 and 3 of the specified AC, and clears the error flags in the Status register. After the data transfer, sets the controller's Busy and Done flags according to the function specified by F. The contents of the specified AC remain unchanged. The format of the accumulator is as follows:

DR	FM MD	DG MD	STARTING HEAD	STARTING SECTOR				-SECTOR COUNT			
0	1	2	3	4	6	7		11	12		15

Bits	Name	Contents or Function
0-1	Drive	Selects a drive (0-3).
2	Format Mode	When set to 1, places the controller in format mode.
3	Diagnostic Mode	When set to 1, places the controller in diagnostic mode.
4-6	Starting Head	Selects the initial head for a data transfer (0-3 for a rigid drive, 0,1 for a flexible drive).
7-11	Starting Sector	Selects the initial sector for a data transfer (0-37 ₈ for a rigid drive, 0-17 ₈ for a flexible drive).
12-15	-Sector Count	Specified the two's complement of the number of sectors for a data transfer.

cylinder), Recalibrate, Read, Write or Format Track operation. A timer keeps them loaded for 15 revolutions (approximately 2.5 seconds) after the operation begins. (Note that a new command to the flexible drive refreshes the timer, which means the heads can be kept loaded indefinitely if a new operation begins within 15 revolutions of a previous operation.)

The time it takes to read or write information on the diskette depends upon to rotational position of the diskette when you start the transfer as well as the number of sectors you wish to transfer. The following factors determine read/write time:

- The time the computer takes to issue the read/write command along with a starting memory address, disc address and sector count, and then process the interrupt when the operation is completed (i.e., the computer's overhead time) - less than 150 μ sec.
- The time the controller takes to initiate the read/write operation, the data channel operation and the program interrupt request (i.e., the controller's overhead time) - less than 400 μ sec.
- The time the drive takes to bring the first sector around - 166.7 msec at nominal 360 rpm. (Note that the controller allows four revolutions before it flags an address error. Thus, it could actually take up to 666.7 msec to find the first sector.)
- The time to transfer the first sector - 9.056 msec.
- The time to transfer an additional sector once the first sector is transferred (one sector time = 10.048 msec.).

The minimum total time to transfer a single sector is therefore less than 9.5 msec, not including the computer's overhead time. For multiple sector transfers, simply add 10 msec times the number of additional sectors.

POWER-UP/POWER-DOWN RESPONSE

When power is first applied to the subsystem, the controller logic is automatically initialized (see IORST). Thus, after power-up, the controller will be idle, waiting for a command. (Note: the drives are not recalibrated when the subsystem is powered up.)

Be certain that the drives are released from the operating system before you power them up or down. Also be sure that the flexible drive is idle before you power the rigid drive down. Finally, be sure the flexible drive is released from the operating system before you insert or remove its diskette.

INITIAL PROGRAM LOAD (IPL)

The disc subsystem has an initial program load features that can transfer a low level bootstrap program from drive number 0 to the CPU. The program must first be recorded on the first sector of the disc (i.e., sector 0 on head and track 0). The IPL sequence transfers the program to the

first 256 locations of the computer's memory bank.

An IPL operation usually occurs when the subsystem is first powered up. The operator can initiate an IPL any time the disc drive is ready. (There are several ways to do this. Refer to information on your specific system for details.) The computer first executes a small bootstrap loader program that initializes the disc subsystem. This program issues an IORST followed by an S device flag command. It then branches to memory location 377₈ and waits (this memory location contains a jump instruction to itself).

The I/O Reset IORST initializes the controller logic and sets the IPL flag to 1. It also clears the memory address register. The S device flag command sets the Busy flag to 1, sets the Done flag to 0 and starts the operation. First the controller directs a recalibrate operation on the drive. It then transfers the sector. When the transfer is completed, the Busy flag is set to 0, the Done flag is set to 1 and a program interrupt request is initiated.

The last word in the sector contains a jump instruction to a location in the bootstrap program. This forces the computer to execute the program after all 256 words are transferred. The IPL flag is cleared the first time the computer issues a Specify Command and Cylinder instruction (DOA).

ERROR CONDITIONS

Error conditions are reported by the Status register. The error flags are not valid until an operation has been completed and the Seek Done or Read/Write Done flag is set to 1. Because the error conditions are quite different for the rigid and flexible drive, we will discuss them separately.

Rigid Drive

Errors During Initial Selection

Ready - If the Ready flag is set to 0 when the rigid drive is accessed, check to see that the power switch is turned on. No commands are processed if the drive is not ready. If the drive becomes not ready when an operation is in progress, that operation is aborted.

Errors While Positioning the Heads

Power Off - If the power switch on the rigid drive is turned off, the operation terminates, a program interrupt request is initiated, the heads are moved to the landing zone and the Error flag is set to 1.

Speed Fault - If the disc's rotational speed falls below a preset minimum during a seek operation, the Unsafe flag is set to 1, the operation terminates, head motion ceases and position information is lost. A recalibrate operation must be performed to recover position information. If the disc's rotational speed falls below a preset minimum during a recalibrate operation, the Unsafe flag is set to 1, the operation terminates and head motion ceases.

1. Recalibrate or seek time.
2. Read or write time.
3. Positioner power-up time.

The read/write heads must be positioned in the proper cylinder before a data transfer can begin. The following factors determine the time it takes to seek to a specified cylinder or recalibrate the positioner to select cylinder 0:

- The time the computer takes to issue the Seek command and then process the interrupt when the operation is completed (i.e., the computer's overhead time) - less than 150 μ sec.*
- The time the controller takes to initiate the seek operation and the program interrupt request (i.e., the controller's overhead time) - 400 μ sec.
- The time the positioner takes to move the heads to the specified track - 15 msec for a single track seek, 60 msec for an average seek and 120 msec for a full stroke independent of direction.

*This is an assumed value for illustrative purposes. Actual overhead time is dependent on the specific software used.

The time it takes to execute a recalibrate operation depends upon the position of the heads when the Recalibrate command is issued. This is so because the positioner first moves the heads to the transition point between the data track zone and the landing zone, and then performs a full stroke reverse seek to track zero. This means a recalibrate operation could take from 150 msec to 540 msec, to which you must add the 550 μ sec overhead time.

The time it takes to read or write information on the disc depends upon the rotational position of the disc when you initiate the transfer, as well as the number of sectors you wish to transfer. The following factors determine read/write time:

- The time the computer takes to issue the read/write command along with a starting memory address, disc address and sector count, and then process the interrupt when the operation is completed (i.e., the computer's overhead time) - less than 150 μ sec.
- The time the controller takes to initiate the read/write operation, the data channel operation and the program interrupt request (i.e., the controller's overhead time) - less than 400 μ sec.
- The time the disc takes to rotate to the last sixteenth of the sector immediately preceding the selected sector, once the controller initiates the read operation or completes the data channel transfer for a write operation - variable (a complete revolution takes 20.2 msec.).
- The time it takes to read the header and then transfer the data block and CRC word - 663 μ sec.
- The time it takes to transfer the data across the data channel - approximately 1.1 msec. is allowed during a multiple sector transfer.
- The time it takes to bring the next sector around for a multiple sector transfer - 3 sector times after the start of the previous sector = 1.9 msec.

The minimum total time to transfer a single sector is therefore less than 2.2 msec, not including the computer's overhead time. For multiple sector transfers, simply add 1.9 msec times the number of additional sectors.

The factors that determine the minimum total time for a single sector format operation are very similar to those for a write operation. The only difference is that the header is not read and the time to write the format on the disc is 673 μ sec.

NOTE: Data channel transfers occur between sectors on a multiple sector transfer. This is why the subsystem can only transfer every third physical sector.

The positioner must be powered up before a seek, recalibrate or data transfer operation can begin. The positioner is not powered up until a command is received. It powers back down if a new command is not received within 2 minutes of the previous command. If the positioner is powered down when a command is received, command execution is delayed by 10 msec. (Note therefore that the first recalibrate operation after the subsystem is powered up will be delayed 10 msec.)

Flexible Drive

Several factors determine the time it takes to access and then transfer data blocks to or from the flexible drive. These factors can be roughly divided into three groups:

1. Recalibrate or seek time.
2. Head load time.
3. Read or write time.

The read/write heads must be positioned in the proper cylinder before a data transfer can begin. The following factors determine the time it takes to seek a specified cylinder or recalibrate the positioner to select cylinder 0:

- The time the computer takes to issue the Seek or Recalibrate command and then process the interrupt when the operation is completed (i.e., the computer's overhead time) - less than 150 μ sec.
- The time the controller takes to initiate the operation and the program interrupt request (i.e., the controller's overhead time) - 400 μ sec.
- The time the positioner takes to move the heads across one track - 3 msec.
- The time the positioner takes to settle the heads when the destination track is reached - 22 msec.

Thus, the total time for a positioning operation is 22.6 msec + (3 msec x number of tracks). For example, a recalibrate operation could take up to 22.6 msec + (3 msec x 76) or 250.6 msec.

The read/write heads must be loaded onto the diskette surfaces before the controller can execute a Read, Write or Format Track command. It takes 52 msec to load the heads. The heads are loaded at the start of a Seek (to a new

Read Status

DIA[f] ac,DKP

0	1	1	AC	0	0	1	F	0	1	1	0	1	1		
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Places the contents of the controller's status flags in bits 0-15 of the specified AC. (Note that bits 0-6 and 9 are always valid for the currently selected drive and currently specified command. Bits 7,8 and 10-15 are only valid when an operation has been completed and the appropriate Done flag is set to 1.) After the data transfer, sets the controller's Busy and Done flags according to the function specified by F. The format of the accumulator is as follows:

R/W	SEEK DONE				FL	WP	BS	US	RDY	SK	EOC	AE	CE	DL	ERR
DN	0	1	2	3						ER					
0	1		4		5	6	7	8	9	10	11	12	13	14	15

Bits	Name	Contents or Function
0	Read/Write Done	Indicates the subsystem has completed a read or write operation.
1-4	Seek Done	Indicates the selected drive has completed a seek or recalibrate operation (only 1 flag can be set at any given time). (Note: the device Done flag is not set to 1 when a seek or recalibrate operation is completed.)
5	Flexible	Indicates that a flexible drive is selected.
6	Write Protect	Indicates that the selected drive is write protected.
7	Bad Sector	Indicates that the subsystem attempted a data transfer on a bad sector of the rigid drive.
8	Unsafe	Indicates that the selected drive is in an unsafe condition. On the rigid drive this may be due to a speed fault, a read/write error (multiple heads selected while writing, no write current when writing, write current when not writing or a clock fault), or a sector fault (sector ended before the data transfer was completed). On a flexible drive this may indicate that it is not ready (i.e., a speed fault occurred, the door is opened, or no diskette or the wrong diskette type is installed). (Note that clearing the Unsafe flag does not remove the unsafe condition. Try powering the drive down and back up).

Bits	Name	Contents or Function
9	Ready	Indicates that the selected drive is ready to accept a command.
10	Seek Error	Indicates that the selected drive was not able to carry out a seek or recalibrate operation within a reasonable time. This will occur if the rigid drive is powered down during a seek or recalibrate operation on a flexible drive. Also indicates an illegal cylinder address accompanied a seek command.
11	End of Cylinder	Indicates that the last data transfer operation attempted to proceed beyond the last sector in the cylinder.
12	Address Error	Indicates that the address read from the address field at the beginning of the sector did not match the address specified by the controller. Also indicates a bad sector on the rigid drive, or a CRC error in the address field on a flexible drive.
13	Checksum Error	Indicates that the checksum read from the disc did not match the checksum calculated by the controller during a read data transfer. Also indicates that a read or write operation on a flexible drive was not completed within a reasonable time.
14	Data Late	Indicates that the data channel failed to respond in time to a data channel request during a data transfer on the flexible drive. Also indicates that the rigid drive was powered down during a read or write operation on a flexible drive, or that a read or write operation on a flexible drive was not completed within a reasonable time.
15	Error	Indicates that one or more of the error flags are set (bits 7,8 and 10-15). Also indicates that the rigid drive was powered down while it was performing an operation (the Ready flag is negated in this case).

Read Memory Address

DIB[f] ac,DKP

0	1	1	AC	0	1	1	F	0	1	1	0	1	1	1	1
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Places the contents of the controller's memory address register in bits 1-15 of the specified AC. Also places the state of the Map Select flag in bit 0 of the specified AC. After the data transfer, sets the controller's Busy and Done flags according to the function specified by F. The format of the accumulator is as follows:

MAP SEL	0	1	15
			MEMORY ADDRESS

Bits	Name	Contents or Function
0	Map Select	If 0, data channel map A is selected. If 1, data channel map B is selected.
1-15	Memory Address	Indicates the location of the next memory word for a data channel transfer.

Read Disc Address And Sector Count

DIC[f] ac,DKP

0	1	1	AC	1	0	1	F	0	1	1	0	1	1	1	1
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Places the contents of the controller's drive select, head, sector and sector count registers in bits 1 and 4-15 of the specified AC. Also places the states of the controller's Format Mode and Diagnostic Mode flags in bits 2 and 3 of the specified AC. (Note that the disc address and sector count word is valid only after an operation is completed and the Done flag is set to 1.) After the data transfer, sets the controller's Busy and Done flags according to the function specified by F. The format of the accumulator is as follows:

DR		FM MD	DG MD	CURRENT HEAD			CURRENT SECTOR					-SECTOR COUNT			
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Bits	Name	Contents or Function
0-1	Drive	Indicates the number of the currently selected drive.
2	Format Mode	When 1, indicates that the controller is in format mode.
3	Diagnostic Mode	When 1, indicates that the controller is in diagnostic mode.
4-6	Current Head	Indicates the head number that is selected for the next sector transfer.*
7-11	Current Sector	Indicates the sector number that is selected for the next sector transfer.*
12-15	-Sector Count	Indicates the two's complement of the number of the number of sectors remaining for a data transfer operation.

*Unless the operation terminates with the Address Error flag set to 1, the head and sector numbers indicate the next logical sector for a data transfer. If the end of the cylinder is reached, the current head and sector numbers are set to 0.

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1. Set up buffer for current track and head 0.
2. Format the track.
3. Update the buffer for current track and head 1.
4. Format the track.
5. Seek to next cylinder (don't go beyond cylinder 114_g).
6. Go to step 1.

When the format operation is initiated, the controller waits until the index mark (hole in the diskette) comes around. It then records the format block, bit by bit, until the index mark appears again. The fill gap in the buffer (342 words) represents 50 percent more than the number of words required to fill out a track if the spindle is rotating at 352.8rpm (minimum speed). When the diskette is rotating at nominal speed (360 RPM), 10,417 bytes are recorded on the track. This breaks down into 16 blocks of 628 bytes followed by 369 bytes of fill gap.

The soft sector technique does not allow you to format individual sectors. If a "hard" address error (i.e., an address error that was not caused by an end of cylinder fault) or CRC error occurs in a given sector, you must reformat the entire track. This means you will first have to retrieve the data recorded in the other sectors, as the format operation will destroy all the information previously recorded in the track.

We suggest you use the following programming sequence to format a track on the diskette. Observe the following precautions before you proceed:

- Check that the Busy flag is set to 0.
- Check that the flexible drive is ready
- Be sure the desired cylinder is selected if you intend to reformat a track
- Be sure the Write Protect flag is set to 0

Issue a *Specify Disc Address and Sector Count* instruction (**DOC**) to the controller with no device flag command. Use the appropriate accumulator bits to select the flexible drive, set the Format Mode flag to 1, and select a head number.

Issue a *Load Memory Address Register* instruction (**DOB**) to the controller with no device flag command. Use the appropriate accumulator bits to specify the 15-bit address of the memory location that contains the first word of the data block.

Issue a *Specify Command and Cylinder* instruction with an **S** device flag command. Use the appropriate accumulator bits to specify a Write command. The **S** device flag command sets the Busy flag to 1, sets the Done flag to 0 and starts the operation. When the index mark comes around, the controller transfers the entire format block, via the data channel, from memory to the flexible drive. Each time a word is transferred, the memory address register is incremented by 1. When the index mark comes around again, the operation is completed and the controller sets the Busy flag to 0 and the Done flag to 1 and initiates a program interrupt request.

Issue a *Read Status* instruction (**DIA**) with a **C** device flag command and check the error flags. If a fault occurred, you may wish to retry the operation.

After you format the diskette for the first time, it would be a good idea to recalibrate the positioner and then step through the tracks and read the sectors. The read operations will check that the track and sector address numbers were correctly recorded in each address header. They will also check that no CRC errors were encountered in the data blocks recorded during the format operation (the format operation records 0401000_g in each word of every sector data block). In addition, you may wish to write and then read random data patterns to check for media defects (the DGC formatter program does this automatically). Finally, it would be wise to check for a seek fault before you reformat a track. Remember that when a track is reformatted, all the data previously recorded on that track is lost.

Seek Fault on the Flexible Drive

To check for a seek fault on the flexible drive, issue a *Specify Disc Address and Sector Count* instruction (**DOC**) with no device flag command. Use the appropriate accumulator bits to select the drive and head and to set the Diagnostic Mode flag to 1.

Then issue a *Load Memory Address Register* instruction (**DOB**) with no device flag command. Use the appropriate accumulator bits to specify the starting memory location for the 3-word address field transfer.

Finally, issue a *Specify Command and Cylinder* instruction (**DOA**) with an **S** device flag command. Use the appropriate accumulator bits to specify a Read Header operation (see the diagnostics section for details). The **S** device flag command sets the Busy flag to 1, sets the Done flags to 0, and starts the operation.

The controller reads the address field in the first sector it encounters and transfers the three address words to memory. It also checks CRC on the address field.

When the transfer is completed, the Busy flag is set to 0, the Done flag is set to 1 and a program interrupt request is initiated. Now issue a *Read Status* instruction (**DIA**) with a **C** device flag command and check for errors. Then check the track address (right justified in the left byte of the first address word) and see if it matches the one specified for the previous seek operation. If it does not, you should recalibrate the drive before issuing a new Seek command.

TIMING

Rigid Drive

Several factors determine the time it takes to access and then transfer data blocks to or from the rigid drive. These factors can be roughly divided into three groups:

the disc.

The controller then locates the sector selected by the *Specify Disc and Sector Count* instruction, initializes the write logic and begins the transfer. Finally, it fetches and disassembles 16-bit data words from the buffer and the drive records the serial data stream. When all 256 words are written, the drive records zeroes for the remainder of the sector.

This operation is repeated for the remaining sectors. Finally, the Busy flag is set to 0, the Done flag is set to 1 and a program interrupt request is initiated.

After the format operation is completed, issue a *Read Status* instruction with a **C** device flag command and check the error flags. If a fault occurred, you may wish to retry the operation.

After you format the disc for the first time, it would be a good idea to recalibrate the positioner and then step through the tracks and issue Read Header diagnostic commands to check for seek errors. In addition, you might write and then read certain data patterns to check for media defects. It is also wise to check for a seek fault before you reformat a selected sector.

You may wish to reformat a sector to set the Bad Sector flag to 1. This will prevent further transfers to that sector and will prevent data loss due to defects in the recording media. Any sector that produces CRC errors is a likely candidate. Before you do this, it would be wise to check for a seek fault.

Seek Fault on the Rigid Drive

To check for a seek fault on the rigid drive, issue a *Specify Disc Address and Sector Count* instruction (**DOC**) with no device flag command. Use the appropriate accumulator bits to select a drive, head and sector, and to set the Diagnostic Mode flag to 1. Then issue a *Specify Command and Cylinder* instruction (**DOA**) with an **S** device flag command. Use the appropriate accumulator bits to specify a Read Header operation (see the diagnostics section for details).

The **S** device flag command sets the Busy flag to 1, sets the Done flag to 0 and starts the operation. First the controller searches for the sector selected by the *Specify Disc Address and Sector Count* instruction. The controller then initializes the read logic, and the transfer begins at the start of the selected sector.

The drive now reads the pre-recorded address field and the controller checks that:

- The track address recorded in the header address matches the track address that accompanied the Seek command
- The head and sector addresses recorded in the address word match the head and sector addresses that accompanied the Read Header command.
- The Bad Sector flag is set to 0.

When the address check is complete, the Busy flag is set to zero, the Done flag is set to one and a program interrupt request is initiated. Now issue a *Read Status* instruction (**DIA**) with a **C** device flag command and check bit 14 (it is set to 1 if an address error occurred). If an error occurred, issue a *Read Disc Address and Sector Count* instruction (**DIC**) and check to see if the track address read from the header matches the one specified for the previous seek operation (the track address appears in the left byte of the accumulator field). If it does not, you should recalibrate the positioner before issuing a new Seek command.

Formatting the Flexible Disc Drive

Before you can format a track on the diskette, you must set up a buffer in memory that contains the binary image of the entire track. The buffer must contain 5350 words. (Each word contains two bytes.) This breaks down into 16 blocks of 313 words each followed by a 342-word fill gap. The first 16 blocks are nearly identical, as shown below. (Only the sector numbers in the address field differ; they should be numbered in sequence, starting with sector 0.) Each word in the fill gap should contain the number 047116g.

Words	Octal Contents
1-10	047116
11-16	000000
17	172765
18	172776
19-20	address field
21	173516
22-31	047116
32	047000
33-37	000000
38	000365
39	172765
40	175500
41-295	040100
296	040367
297-313	047116

The address field must be set up as follows:

Word 19

0	TRACK							0	0	0	0	0	0	0	0	HD
0	1						7	8	9	10	11	12	13	14	15	

Word 20

0	0	0	0	SECTOR				0	0	0	0	0	0	0	1	0
0	1	2	3	4			7	8	9	10	11	12	13	14	15	

Once the buffer has been set up, only the address fields need to be changed to format additional tracks. We suggest you proceed as follows;

PROGRAMMING

To program the disc subsystem for read or write data transfers, you must first select a drive and position its read/write heads over the desired cylinder. You can then issue a Read or Write command, select a starting head and sector and specify a sector count for the data transfer. (Please note that the disc must be formatted before data transfers can occur. Refer to the section on formatting for details. Also note that a sector cannot be read on the rigid drive without encountering errors unless data was previously recorded.)

Positioning operations move the read/write heads to the desired cylinder for a data transfer or a format operation. When a Recalibrate command is issued, the selected drive moves its heads to cylinder 0. (The drives detect mechanical reference points to locate cylinder 0. The method used by the rigid drive, and the resulting recalibrate time, is quite different from those of the flexible drive.) When a Seek command is issued, the positioner moves the heads the required number of steps to select the desired cylinder. It is important to note that the positioner must be recalibrated before the first seek operation can occur. In addition, the positioner on a flexible drive must be recalibrated if the drive fails to execute a command within a reasonable time period. The subsystem never recalibrates the positioner automatically.

Read and write operations can transfer up to sixteen 256-word data blocks between the CPU and the disc. Data is transferred via the data channel, starting at the memory location dictated by the *Load Memory Address Register* instruction **DOB**. Flexible drive transfers are double buffered to improve immunity to data late conditions. Rigid drive transfers are fully sector buffered to prevent data late conditions. (Fully buffered transfers occur in two phases. In one phase, data flows between the buffer and the disc. In the other phase, data flows between the buffer and the CPU. This means that the subsystem cannot transfer contiguous physical sectors on the rigid drive. The controller therefore implements an automatic mapping function wherein every third physical sector on the disc is assigned a contiguous logical address. This mapping function is transparent to the program, but does affect timing.)

Before you initiate any operation, you should check that the Busy flag is set to 0. Then issue a *Specify Disc Address and Sector Count* instruction (**DOC**) to select a drive. Follow up with a *Read Status* instruction (**DIA**) and check that the selected drive is ready. The *Read Status* instruction should be also be issued after each operation to check for errors. (The following discussion assumes that no errors occur during either phase. Error conditions are discussed later in the text.)

Position the Heads

We suggest you use the following programming sequence to position the heads in a selected cylinder.

FORMATTING

The disc subsystem will not function properly until the data surfaces are formatted. The format delineates an address field and a 256-word data field in each sector of every data track on the recording disc. The address field of a sector is a coded header that precedes the data block. The format operation records the field at a specific location within the sector to give the read and write control circuits enough time to initialize and settle before the field is read.

The rigid drive uses a "hard sector" technique to locate sectors. A sector counter in the drive monitors mechanical reference points on the disc platter to locate sectors. When the desired sector for a data transfer comes around, the controller checks the address field before it transfers the data block. The address field identifies the sector's physical address and contains a bad sector flag. This allows the subsystem to check for seek errors, head select errors and sector count faults. In addition, the bad sector flag can be set to 1 to prevent read or write data transfers on unreliable sectors.

The flexible drive uses a "soft sector" technique to locate sectors. This means the controller must read address fields until it finds the one with the desired track and sector address. (Note that the address field also identifies the surface number, but the controller doesn't check it.) Two CRC bytes accompany to test the validity of the address information. The soft sector method requires you to format an entire track at once. This means that you cannot reformat selected sectors.

Each diskette and rigid disc is completely formatted before it leaves the factory. Data General supplies a stand-alone program that will format all the sectors on each surface of the disc or diskette. The program can also reformat selected sectors on the rigid disc to allow you to set Bad Sector flags. (The program cannot reformat selected tracks on a diskette. Should you wish to do this, you must recover the recorded data and then format the entire diskette. The formatter program is available on diskette (DGC No. 095-001140) and its operation is described in a companion listing (DGC No. 096-001140). Whenever any sector or track is reformatted, the previously recorded information is lost. Formatting must be done independently of and before initializing the disc with a Data General operating system.

Format operations on the rigid and the flexible drives are very different. We will therefore discuss them separately.

Formatting the Rigid Disc

A format operation on the rigid drive records a 256-word data block starting at the beginning of a sector. It then records zeroes throughout the remainder of the sector. The 256-word data block must be set up in the computer's memory before the Format command is issued. This block takes the following form:

Words 1-10₆

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Word 11₆

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Word 12₆

TRACK								HEAD			SECTOR				
128	64	32	16	8	4	2	1	4	2	1	16	8	4	2	1
0															
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Word 13₆

BD	SC	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		

(The bad sector flag is set to 1 to prevent data transfers to or from that sector.)

Words 14₆-400₆

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		

We suggest you use the following programming sequence to format the rigid disc. Observe the following precautions before you proceed:

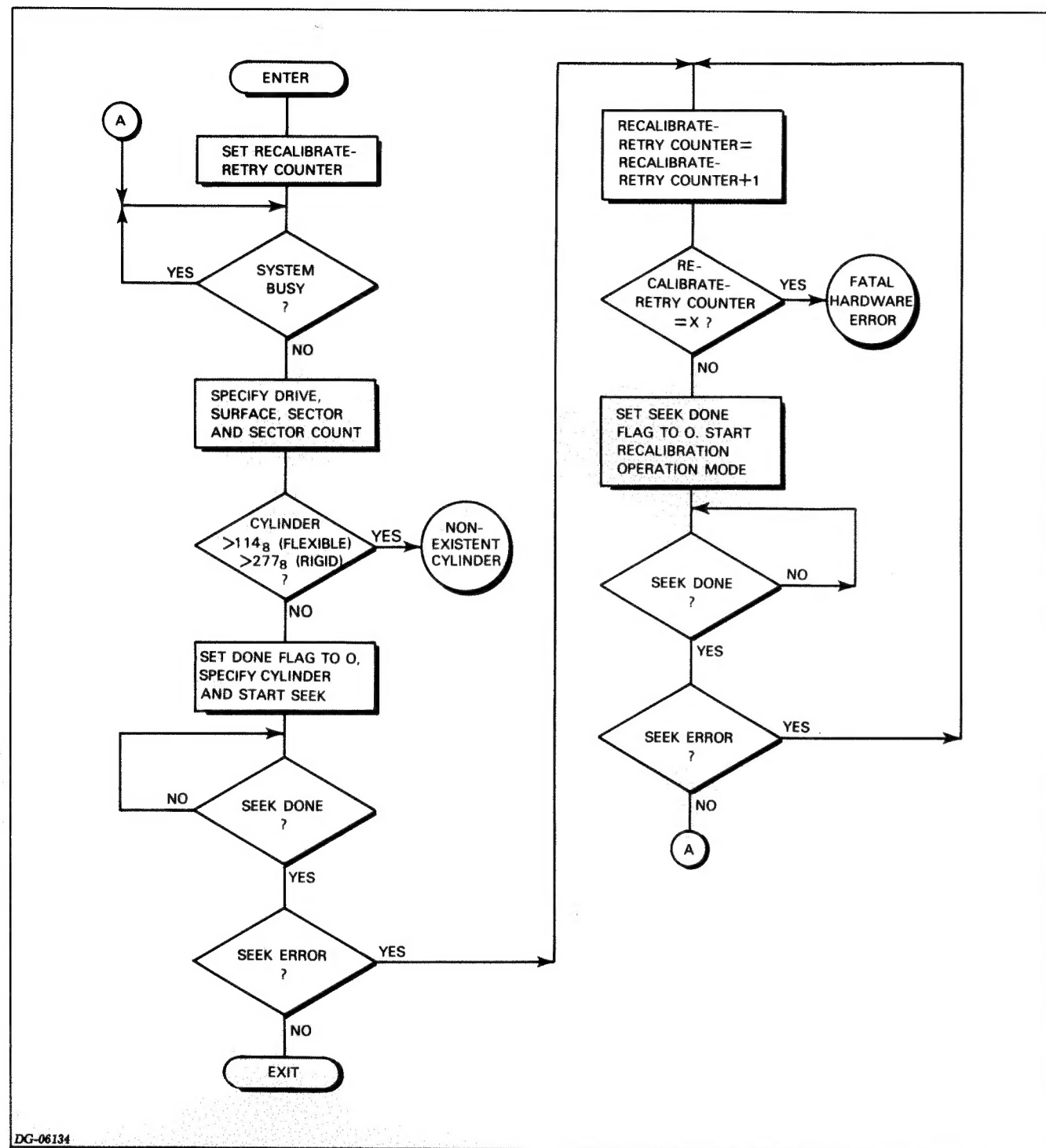
- Check that the Busy flag is set to 0.
- Check that the disc drive is ready.
- Be sure the desired cylinder is selected if you intend to re-format a sector.
- Be sure the Write Protect flag is set to 0.

Issue a *Specify Disc Address and Sector Count* instruction (**DOC**) to the controller with no device flag command. Use the appropriate accumulator bits to place the controller in Format Mode, select a drive, starting head (0-3) and sector (0-37₆), and specify a sector count.

Issue a *Load Memory Address Register* instruction (**DOB**) with no device flag command and use the appropriate accumulator bits to specify a Write command. The **S** flag command sets the controller's Busy flag to 1, sets the Done flag to 0 and initiates the format operation.

Issue a *Specify Command and Cylinder* instruction (**DOA**) with an **S** device flag command and use the appropriate accumulator bits to specify a Write command. The **S** flag command sets the controller's Busy flag to 1, sets the Done flag to 0 and initiates the format operation.

The controller first transfers the 256-word format data block for the starting sector, one word at a time, from the computer's memory bank to the buffer via the data channel. Each time a word is transferred, the Memory Address register is incremented by one. When the transfer is complete, the controller prepares to record the data on

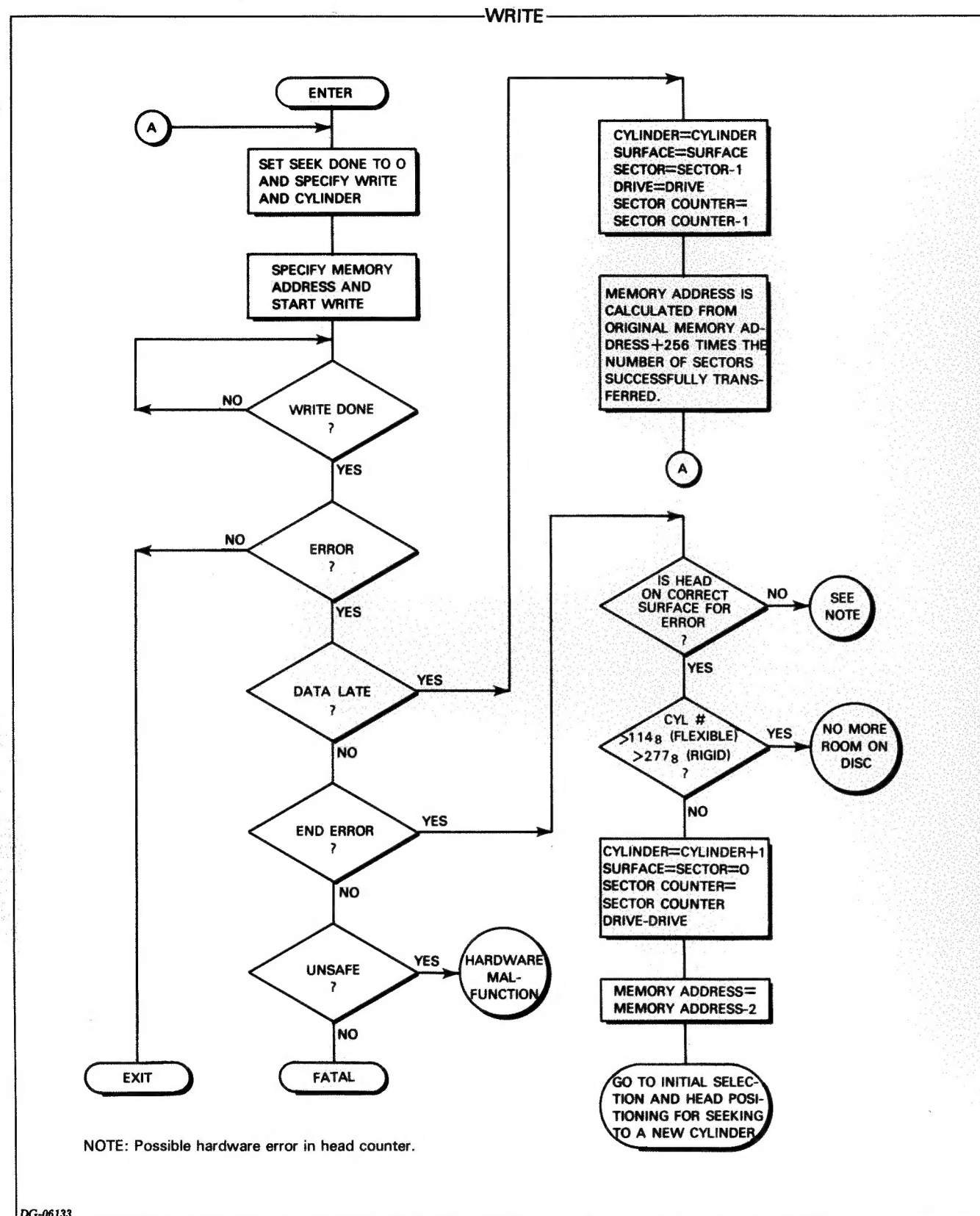


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Figure 1

Issue a *Specify Command and Cylinder* instruction (**DOA**) with a **P** device flag command to move the heads to the desired cylinder. Use the appropriate accumulator bits to specify a Recalibrate command (seek to track 0) or a Seek command and a track number. (Remember that the selected drive must be recalibrated before it can process the first seek command.)

The **P** flag command sets the Seek Done flags to 0 and starts the positioning operation. (The Ready flag is set to 0 if the rigid drive is seeking.) When the operation is completed, the appropriate Seek Done flag is set to 1 and an interrupt request is initiated.



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Figure 3

After the seek operation is completed, issue a *Read Status* instruction (**DIA**) with a **C** device flag command. Check the Unsafe and Seek Error flags to see that no errors occurred during the operation. If a recoverable error occurred, you may wish to retry the operation.

Read

We suggest you use the following programming sequence to read data from the disc.

Issue a *Specify Command and Cylinder* instruction (**DOA**) with no device flag command, using the appropriate accumulator bits to specify a Read command along with the correct cylinder address. The cylinder address should match the one issued for the last seek operation on the selected drive. It is used by the address checking circuits to be sure the proper cylinder is selected for the data transfer.

Issue a *Load Memory Address Register* instruction (**DOB**) with no device flag command and use the appropriate accumulator bits to specify the address of the first memory location to receive the read data block(s).

Issue a *Specify Disc Address and Sector Count* instruction (**DOC**) with an **S** device flag command. Use the appropriate accumulator bits to select a drive, head and starting sector, and specify a sector count. Be careful not to specify a multiple sector transfer that would exceed the capacity of the disc. Also remember that a multiple sector transfer that starts with one head can continue with the next. The **S** flag command sets the controller's Busy flag to 1, sets the Done flags to 0 and initiates the read operation.

If the rigid drive is selected, the controller locates the sector selected by the *Specify Disc Address and Sector Count* instruction, initializes the read logic, and starts the transfer. The drive first reads the pre-recorded address field and the controller checks that:

- The track address recorded in the address word matches the track address in the *Specify Command and Cylinder* instruction (**DOA**).
- The head and sector address recorded in the address field match the head and sector address that accompanied the Read command.
- The Bad Sector flag is set to 0.

If an error occurs, the operation stops at the end of the address check, and the data transfer is aborted. In this case, the Address Error flag is set to 1, and a Read Rigid Data Shift Register diagnostic operation would return the faulty address word (more on this later).

If the address check is successful, the drive reads the serial data stream and the controller assembles 16-bit data words and stores them in the buffer. The controller also calculates a 16-bit cyclic redundancy checkword as the data stream is read. When all 256 words are read, the controller compares the calculated checkword to the one that follows the data field (calculated and recorded during the previous write operation). If the checkwords don't match, the Checkword

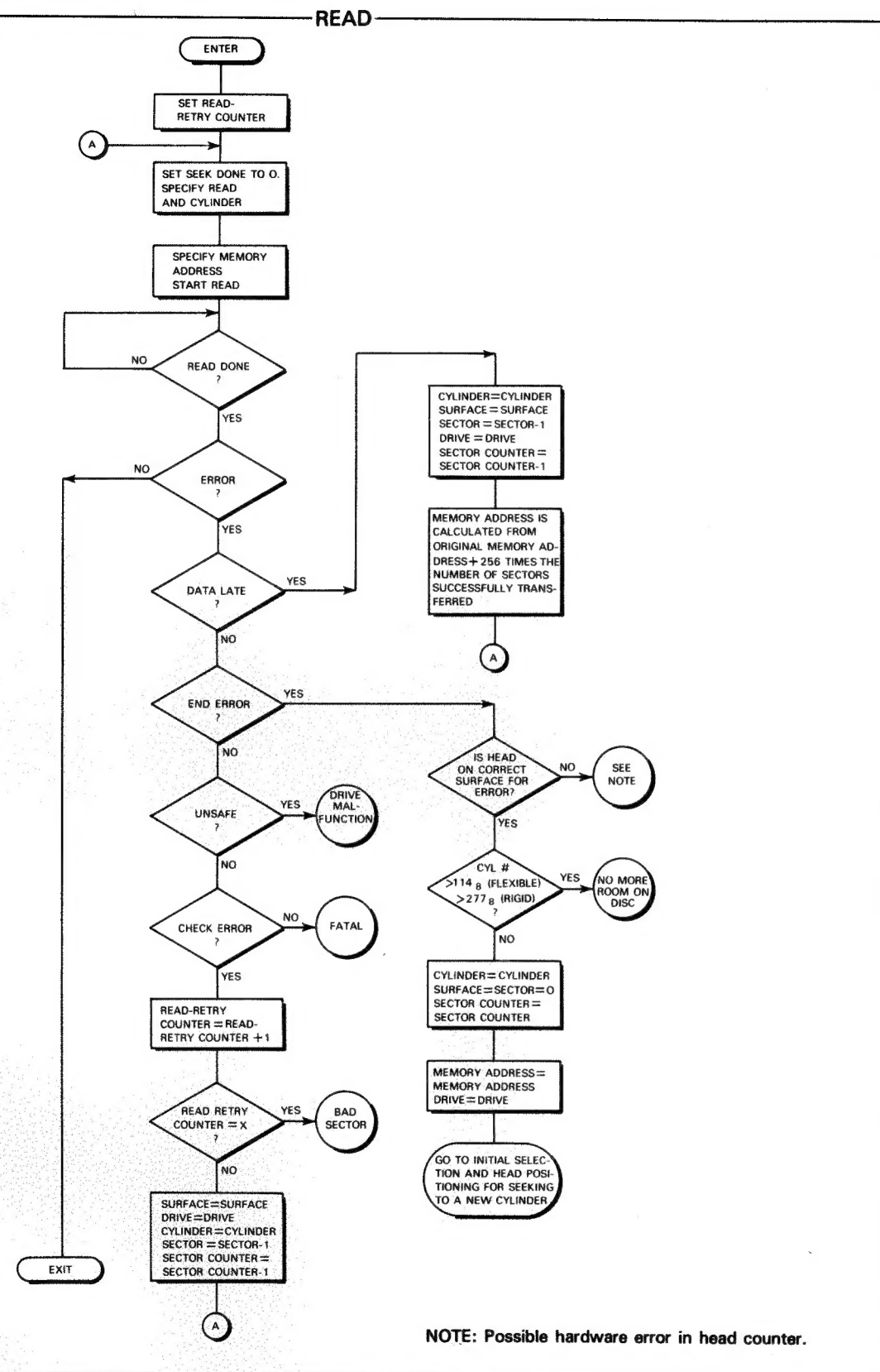
Error flag is set to 1.

The controller now transfers all 256 words, one at a time, to the computer's memory bank via the data channel. Each time a word is transferred, the Memory Address register is incremented by one. The remaining sectors are transferred in a similar manner. When all the sectors are read, the Busy flag is set to 0, the Done flag is set to 1 and a program interrupt request is initiated.

If a flexible drive is selected, the controller reads address fields until it finds the starting sector address. If it can't find the starting sector after four revolutions of the flexible disc, the operation terminates and the Address Error flag is set to 1. (Note that the controller checks the sector address and the track address in the address field. Thus, a seek fault will cause an address error.) In addition, if the controller encounters a CRC error when it attempts to read the address field, the operation terminates and the Address Error flag is set to 1.

If the address check is successful, the drive reads the serial data stream and the controller assembles 16-bit data words and transfers them to the computer's memory bank via the data channel. Each time a word is transferred, the memory address register is incremented by one. The controller calculates a CRC word as the transfer proceeds. When all 256 words are read, the controller compares the calculated checkword to the one that follows the data block (calculated and recorded during the previous write operation). If the checkwords don't match, the Checkword Error flag is set to 1. The remaining sectors are transferred in a similar manner. When all the sectors are read, the Busy flag is set to 0, the Done flag is set to 1 and a program interrupt request is initiated.

After the read operation is completed on the selected drive, issue a *Read Status* instruction (**DIA**) with a **C** device flag command and check the error flags. If a recoverable error occurred, you may wish to re-initialize the positioning mechanism or retry the transfer.



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Figure 2

Write

We suggest you use the following programming sequence to write data onto the disc. Be sure the Write Protect flag is set to 0 before you proceed.

Issue a *Specify Command and Cylinder* instruction (**DOA**) with no device flag command and use the appropriate accumulator bits to specify a Write command along with the correct cylinder address. The cylinder address should match the one issued for the last seek operation on the selected drive. It is used by the address checking circuits to be sure the proper cylinder is selected for the data transfer.

Issue a *Load Memory Address Register* instruction (**DOB**) with no device flag command and use the appropriate accumulator bits to specify the address of the first memory location that contains the write data block(s).

Issue a *Specify Disc Address and Sector Count* instruction (**DOC**) with an **S** device flag command. Use the accumulator bits to select a drive, head and starting sector, and specify a sector count. Be careful not to specify a multiple sector transfer that would exceed the capacity of the disc. Also remember that a multiple sector transfer that starts with one head can continue with the next head. The **S** flag command sets the controller's Busy flag to 1, sets the Done flag to 0 and initiates the write operation.

If the rigid drive is selected, the controller first transfers all 256 words, one at a time, from the computer's memory bank to the buffer via the data channel. Each time a word is transferred, the Memory Address register is incremented by one. When the transfer is complete, the controller prepares to record the data on the disc.

The controller now locates the starting sector and checks the address field the same way it did for a read operation. If the address check is successful, the controller fetches and disassembles 16-bit data words from the buffer and the drive records the serial data stream. The controller calculates a CRC word as the transfer proceeds. When all 256 words are written, the final checkword is appended to the data block. The remaining sectors are transferred in a similar manner. When all the sectors are written, the Busy flag is set to 0, the Done flag is set to 1 and a program interrupt request is initiated.

If the flexible drive is selected, the controller locates the starting sector as it does for a read operation. It then fetches 16-bit data words one at a time from the computer's memory bank via the data channel and disassembles them into a serial data stream that is recorded by the drive. Each time a word is transferred, the Memory Address register is incremented by one. The controller calculates a CRC word as the transfer proceeds. When all 256 words are written, the final checkword is appended to the data block. The remaining sectors are transferred in a similar manner. When all the sectors are written, the Busy flag is set to 0, the Done flag is set to 1 and a program interrupt request is initiated.

After the write operation is completed, issue a *Read Status* instruction (**DIA**) with a **C** device flag command and check the error flags. If a recoverable error occurred, you may wish to re-initialize the positioning mechanism or retry the transfer.